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We think, we smell, we remember: The effect of smell on memory for chemistry lab learning

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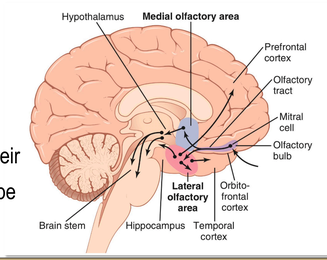
Abstract

The traditional five senses are the primary receptors of external stimuli for the brain. While tactile learning and visual observations are integral to the chemistry laboratory, olfaction is a sense that should be considered part of an educator's repertoire. Previous studies have discovered that our sense of smell plays a significant role in triggering memories. Moreover, specific scents like vanillin can prompt anamneses to recall previous experiences. A sample of 61 college students was employed for a three-week pretest-posttest control group experimental design. In the first week, participants conducted a chemical reaction to synthesize isoamyl acetate, the familiar and nontoxic scent of bananas. Over two additional weeks, participants in the treatment group were exposed to the same banana smell, while those in the control group were not. Both groups took an identical pre- and post-test designed to measure procedural recall. T-test analyses showed a statistically significant impact (at the $p < 0.05$ level) of smell on the recollection of simple procedural memory. Although this study compared groups using a simple procedure, research has yet to evaluate the significance of smell in complex experimentation. Ideally, the findings of this study may inspire the development of innovative pedagogical strategies infused with the commonly overlooked sense of smell.

Introduction

Introduction

- The link between smell and memory is powerful.
- In the classroom, **sensory stimuli**, such as tactile and visual components, are integral to the curriculum.
- **Multisensory learning** techniques incorporate the use of sensory modalities in instructional strategies.
- **All incoming sensory** information, **except for smell**, is sent **first to the thalamus**, which monitors the strength and nature of the sensory impulses and uses the individual's past experiences to determine the data's degree of importance (Sousa, 2022).
- In a laboratory-based approach to odor memory, participants artificially encounter odors in a undergraduate chemistry laboratory setting – the **"encoding phase"** – and then are re-exposed to the same odor in the second period – the **"test phase"** (Saive et al., 2014).
- While tactile learning and visual observations are integral to the chemistry laboratory, **olfaction** is a sense that **should be considered part of an educator's repertoire**.
- The novelty is that students completed a **hands-on experiment that led to the smell naturally** instead of a pre-made artificial odor. In other words, the **students encountered the smell due to their creation**.
- Our hypothesis was that when students complete the esterification reaction and **create the banana smell**, their **procedural memory** would be **positively** impacted.



Method

Participants

- Convenience sample of students enrolled in General, Organic, and Biological (GOB) chemistry (n = 61).

Exclusion Criteria

- Students who listed an allergy to fruit or have had an allergic reaction to fruit ingredients.
- Students under the age of 18
- Students who could not smell at the time of study.

Research Design

- Pretest-posttest control group experimental design

Table 1

Descriptive statistics for synthesis, post-week 1, and post-week 2 scores by group

Variables	Week: Synthesis week	Post-week 1	Post-week 2
Without Smell (Control)	S	O	O
With Smell (Treatment)	S	X_1	X_2

Note. N's for with- and without-smell groups were 36 and 25, respectively. S = first experiment that synthesized the banana odor. O = control; without the presence of odor. X_1 = post-week 1 (post-week assessment after one week). X_2 = post-week 1 (post-week assessment after one week). Without smell = control group; did not receive banana smell during post-weeks 1 and 2. With smell = experimental group; received banana smell during post-weeks 1 and 2.

Synthesis Week (Encoding Phase)

- Both With Smell (Treatment) and Without Smell (Control) Groups completed the experiment and took a "pre-test" about the lab procedure, reagents, and materials.

Post Weeks 1 and 2 (Test Phases)

- With Smell (Treatment) Group completed a "post-test" with the presence of the banana smell.
- Without Smell (Control) Group completed a "post-test" without the presence of the banana smell.
- The "post-test" was almost identical to the "pre-test."

Safety Considerations

Safety Consideration

- Before the start of this study, combinations of alcohols, carboxylic acids, and acid catalysts were **screened for safety and reliability.**
- All **safety considerations aligned with the 2023 ACS Guidelines** for Undergraduate Chemistry Programs described by the American Chemical Society (ACS, 2023).
- **All students and instructors wore personal protective equipment (PPE)**, such as gloves, goggles, and lab coats throughout the entirety of the data collection period.
- Before starting each lab period, **the researchers demonstrated proper wafting techniques** because direct inhalation of any chemical may cause irritation.
- All organic compounds were safely disposed at the conclusion of encoding and test phases.

Chemical Reaction: Fisher Esterification

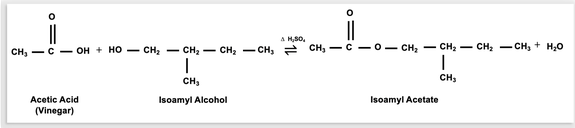
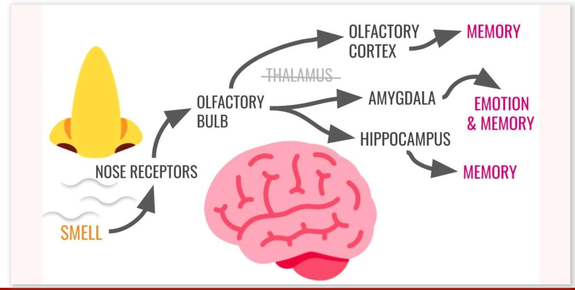


Figure 1 Esterification reaction of acetic acid and isoamyl alcohol in the presence of a catalyst – sulfuric acid. The products were isoamyl acetate (the banana scent) and water.

Smell Pathway: From Nose to Brain



Results

Results

- The ester product was **generally perceived as pleasant** by many participants (78.7%).
- After one week, the **with-smell group retained 10.6% more than their without-smell counterparts** (average score 97.0% vs. 86.4%).
- Similarly, the **with-smell group recollected 94.5%** of the materials from the synthesis over two weeks, compared to **80.8% for the without-smell group**.
- In other words, the **with-smell group outperformed the without-smell group by 13.7%**, F (1,68) = 2.00, p = .004. (T-Test)
- The effect size, as measured by **Hedges' g, was g = 0.29**, indicating a **small effect** (Lovakov & Agadullina, 2017).

Table 2

Descriptive statistics for synthesis, post-week 1, and post-week 2 scores by group

Variables	n	*M*	*SD*	% Correct	Min	Max	Range	SE
Control (Without Smell)								
Synthesis Week	25	11.78	4.79	-	7.0	16.0	9.0	.44
Post Week 1	25	10.18	2.36	86.4	5.0	16.0	11.0	.47
Post Week 2	25	9.52	5.45	80.8	5.0	15.0	10.0	.46
Treatment (With Smell)								
Synthesis Week	36	12.04	4.89	-	7.0	17.0	10.0	.37
Post Week 1	36	11.68	2.20	97.0	7.0	17.0	10.0	.37
Post Week 2	36	11.38	5.75	86.4	6.0	17.0	11.0	.46

Note. Synthesis Week = The encoding week; all students completed the esterification reaction. Post Week 1 = Exactly one week after the encoding week. Post Week 2 = Exactly two weeks after the encoding week. Treatment (With Smell) = Group that received banana odor during post-weeks 1 and 2; Control (Without Smell) = Group that did not receive banana odor during post-weeks 1 and 2.

Discussion

Discussion

- The data revealed that **students who were exposed to the smell remembered significantly more** chemistry-related lab procedure and materials than their no-smell counterparts. The effect of smell on memory produced a **small effect size (g = 0.29).**
- The results of this study imply that **smell can be an effective sensory cue for memory**. More specifically**, students** who were re-exposed to the banana smell in the test phase better **remembered the reagents, catalyst, equipment, and procedural steps.**
- **Chemistry instructors** may use this **neuroscientific lens** to incorporate **multisensory learning techniques** to **reinforce theoretical concepts** from the lecture.
- This study was not the first to measure the **effect of smell on memory** (i.e. Sellaro & Colzato, 2017); however, this experiment presents a **novel way** through which to observe the **dynamic methods in the chemistry lab** and, in turn, mirror the beautiful dynamicity of the **olfactory brain**.

Limitations

Limitations

- Sample Size (n = 61).
- The Scale: Questions were not proven to be validated or reliable; rather, the questions represented major components of the reaction, such as procedural steps and reagents.
- Wafting Technique and Odor Threshold.
- Carryover memory from the lecture to the lab setting.
- Student perception of the synthesized smell.

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